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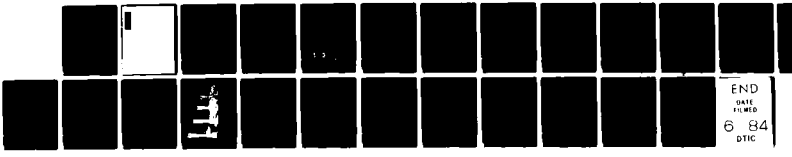

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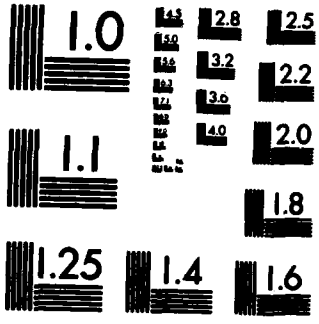

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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The 95 gpm in-line inductor is being considered as a replacement for the portable FP-180 water motor proportioner which dispenses Aqueous Film Forming Foam (AFFF solution) for fire fighting purposes. The inductor has no moving parts and will produce consistent results dependent upon inlet pressures. The purpose of this project was to test and evaluate the performance and efficiency of five commercially available inductors with regard to concentration of AFFF produced, nozzle pressure, and flow rate across a range of inlet pressures ranging from 75 psi to 200 psi. All units performed satisfactorily. Two units, however, which had longer outlet throats and taper of 7° demonstrated more efficient performance than the other units. It is recommended that a MIL SPEC be written to incorporate specific features of these units as well as additional changes necessary to provide a reliable unit for shipboard use.

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EVALUATION OF 95 GPM INDUCTORS FOR AQUEOUS FILM FORMING FOAM

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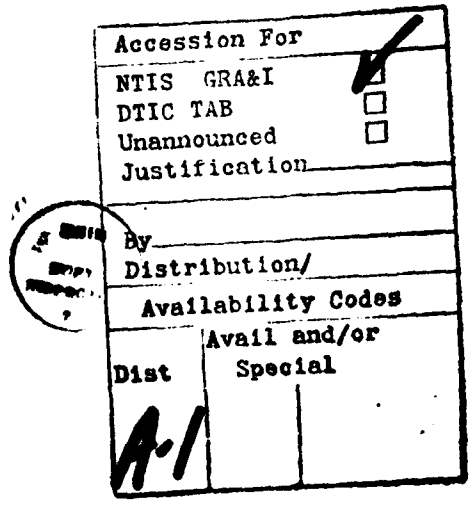

EVALUATION OF 95 GPM INDUCTORS FOR AQUEOUS FILM FORMING FOAM

BACKGROUND/INTRODUCTION

Early History

The use of Aqueous Film Forming Foam (AFFF) for the extinguishment of Class B fires on board ships requires the introduction of AFFF liquid concentrate into a sea water supply coming from the fire main on the way to an application device. Because the fire mains are not dedicated only to this purpose, AFFF injection is usually accomplished at a point near the scene of the fire at the proper time. In order to achieve an acceptable level of extinguishing capability, a minimum concentration of agent (3.5 percent with the current 6 percent type materials) must be present. For maximum efficiency (economically and logistically), the concentration of AFFF should not exceed the design value, currently 6 percent. A variety of devices are used to inject AFFF, such as balanced pressure proportioners, injection pumps and inductors.

The number of variables in the system, such as fire main pressure, nozzle variety, number of nozzles, concentrate viscosity and operating conditions means that the introducing device must have some degree of sophistication in order to achieve proportioning of agent in addition to simply boosting it from atmospheric to fire main pressure.

For known hazardous locations, proportioners may be permanently piped into an installed system while in other cases, they serve as portable devices to be carried to the scene, together with 5-gallon pails of concentrate. Some foam-making nozzles are constructed with an integral inductor and pick-up tube for use at the end of the hose line.

Background

The inductor is a simple, low cost device which will take AFFF concentrate from a container at atmospheric pressure and introduce it into a hose line. It does this by constricting the cross-sectional area of flow to a point where the velocity is high enough to create a vacuum in accordance with Bernoulli's principle. By providing a proper transitional upstream approach to the throat and an even more gradual transition downstream out of the throat, permanent losses from turbulence and friction are minimized.

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Although the inductor has been well known for many years, it has not been employed on Navy ships. Perhaps this has been because of its relatively high pressure drop, its inflexibility to accommodate differing flow rates, an abrupt cutoff in pickup from too long a hose or too high a nozzle elevation and the requirement for a relatively high inlet pressure. In theory, at least, the FP-180 water motor proportioner was not subject to these disadvantages. It could handle flows of from 60 to 220 gpm, thus feeding multiple nozzles or sprinkler heads or combinations thereof without adjustment or controls. In order to accept the inductor as a replacement for portable proportioners and the injection pump for fixed proportioners, it has been necessary to rethink some of the standard procedures for shipboard fire fighting. For purposes of the current application as a portable device, it is being assumed that the inductor will supply a single hose line nozzle of known capacity and that the operational limitations of the inductor will be defined for the Fleet so that satisfactory performance will be obtained.

The inductor has no moving parts and will provide consistent performance over long periods of time as long as the throat or inducting orifice are not damaged. Because the inductor performance will vary as a function of its design, each inductor will have an inlet pressure range at which it will perform better than at other ranges.

OBJECTIVES

- Test and evaluate the performance of commercially available 95 gpm inductors to determine their suitability as a replacement for the portable FP-180.
- Determine the specific operating characteristics of the commercial inductors, the effect of height on inductor performance and the effect of varying hose length.
- Provide specific information and recommendations for the development of a MIL SPEC for 95 gpm inductors.

TEST PLAN AND PROCEDURES

Commercial Inductors

The first phase in the testing program was to acquire several commercial inductors and evaluate their performance across a range of inlet pressures and flow rates. Inductors are rated by the capacity in gpm of the nozzle they are used with. For example, a 95 gpm inductor is designed for use with a 95 gpm nozzle at a nozzle pressure of 100 psi.

Five models were selected for the nozzle tests:

(1) Akron Brass Co., Model 2900 (the only 90 gpm model tested)

(2) Akron Brass Co., Model 2950 (95 gpm)

(3) Elkhart Brass Mfg. Co., Model 241-95 (95 gpm)

(4) Feecon Corp., Model L-95C (95 gpm)

(5) National Foam Systems Inc., Model LP-9A-165-200 (95 gpm)

All are designed for use with 1-1/2" hose lines. These units are shown in Figure 1. Their physical configurations are quite different with the exception of throat size and the inlet and outlet diameters of 1-1/2". These physical characteristics are noted in Table 1 below.

Table 1
PHYSICAL CHARACTERISTICS OF INDUCTORS

	Akron Brass 2900	Akron Brass 2950	Elkhart Brass Mfg. Co.	Feecon Corp. Model L-95-C	National Foam Systems Inc. Model LP-9A-165-200
Length	9½"	9½"	13"	7½"	11"
Outlet Taper	10°	10°	7°	7°	7°
AFFF Inlet Orifice	Non-Adjustable	Non-Adjustable	Adjustable thru full range 0%-6%	Adjustable 1%-3%-6%	Non-Adjustable
Check Valve	Plastic Ball	Plastic Ball	Steel Ball	Plastic Ball	Brass Flapper Valve
Pickup Tube Connection Diameter	2"	2"	7/8"	3/4"	7/8"
Inlet Pressure Required for Maximum Performance	200 PSIG	200 PSIG	200 PSIG	200 PSIG	200 PSIG

It should be noted that the pick-up tube attachment sizes and locations are different for each manufacturer.

The Elkhart inductor has a full-range adjustable orifice which will produce 6% concentrations in less than the full open position. This is not a desirable feature for shipboard use because it could easily be adjusted to provide the wrong percentage of concentrate. Since only 6% concentrate is used, there is no value to an adjustable unit in these conditions. In the worst case, it could be adjusted to 0% and eliminate the AFFF completely.

The adjustable orifice on the Feecon inductor is designed to allow 1%, 3% or 6% concentrate to be used. It could, however, be replaced by a single orifice since all MIL SPEC AFFF in use on board ship is 6%.

The taper of the outlet is designed to reduce the friction and reduce pressure drop and increase the flow. Since we had four different tapers, this test provided an opportunity to study this aspect of the inductor.

TEST PLAN

Purpose

A primary purpose of the tests was to determine the operational characteristics of the commercial inductors and their suitability for shipboard use as a replacement for the portable FP-180.

Test Set-Up

All tests were conducted using the test set-up shown in Figure 2. The use of the digital scale allowed regular checks on the calibration of the flow meter. All data were collected by the Daytronic Corporation data collection system in 1 second scans. All transducers and flow meters were calibrated prior to initiation of testing and rechecked during the test procedure.

The use of the Daytronic scanner meant that all data collected were from the same one second in time, leading to more accurate data than manual recording would yield.

The 95 gpm nozzle, in accordance with MIL-N-24408, was flow tested at 100 psi nozzle pressure and produced 97.5 gpm. This nozzle was used for all tests.

The following tests were utilized to determine the operational characteristics of the inductors.

Test 1 Operational Characteristics of Inductor Alone

Each inductor was operated with inlet pressures of 75, 100, 125, 150 and 200 psi. The back pressure was increased until the vacumn in the inductor was reduced to a point where it no longer induced AFFF into the water stream and the concentration of agent was reduced to zero. The data collected during this test were:

(a) Water flow (gpm)
(b) Concentrate flow (gpm)
(c) AFFF concentration calculated from (a) & (b)
(d) Inlet pressure (psi)
(e) Throat pressure (psi)
(f) Outlet pressure (psi)

(g) Nozzle pressure (psi)
(h) Pressure drop calculated from (d) & (f).

The results of this test are a series of "knee" curves which show the performance curves of the inductor. These are shown in Figures 3A - 3E.

Test 2 Operational Characteristics With 50'of 1-1/2" Hose and a MIL-N-24408 Akron 95 gpm Nozzle

The purpose of this test was to measure the flow, concentration and pressure characteristics at 75, 100, 125, 150 and 200 psi inlet pressure. The test results are given in Tables 2, 3, and 4 in the Test Results and Discussion section of this report.

Test 3 Height Test

One inductor was tested at heights of 3, 13, 23, and 33 feet across the full range of inlet pressures to measure the effect of height on induction capability. The 95 gpm nozzle (MIL-N-24408) was used with both 100 and 150 feet of 1-1/2" hose. Results are shown in Table 5 in the Test Results and Discussion section of this report.

The Akron 2900 (90 gpm) inductor was selected for this test because the other four had demonstrated superior performance, thus, the 2900 would be expected to be the least capable in the height test.

AFFF was used in the height tests and in initial flow tests. After comparison with water, and seeing no noticeable difference in data, the AFFF was replaced by water for the subsequent flow tests.

TEST RESULTS AND DISCUSSION

General

Inductors are designed to produce a vacuum at the throat and induce the AFFF into the water stream. The amount of agent induced is a function of design, inlet pressure and orifice size in the pick-up line. Flow, on the other hand, is primarily affected by the outlet throat where friction losses will reduce the amount of flow.

The primary variables in the inductor performance are:

(1) AFFF concentration percentage over a wide range of inlet pressures,

(2) flow rate over the pressure range,

(3) pressure drop across the inductor.

In evaluating the inductors, these factors became the primary criteria:

(1) ability to maintain a stable 6% concentration across a wide range of inlet pressures,

(2) maximum flow rate across the pressure range,

(3) nozzle pressure,

(4) design features which were likely to be either assets or liabilities in shipboard use.

Concentration Stability

Table 2 depicts the concentration data obtained for each inductor. All of the units produced a minimum of 6% AFFF concentration across the pressure range, however, the National unit provided the most consistent performance ranging from 6.3% to 7.6%, which would provide the most efficient use of AFFF concentrate.

The performance of the Akron units improved considerably as the inlet pressure approached 200 psi, since the AFFF concentration decreased from a high of 9.5% to 7%.

TABLE 2

AFFF CONCENTRATION AT VARIOUS INLET PRESSURES

75 PSI	% CONC.	100 PSI	% CONC.	125 PSI	% CONC.	150 PSI	% CONC.	200 PSI	% CONC.
National	7.0	National	7.5	National	7.6	National	7.1	National	6.3
Elkhart	7.0	Elkhart	7.7	A-2900	7.9	A-2950	7.2	A-2950	6.3
Feecon	7.1	Feecon	8.5	Elkhart	8.2	Elkhart	7.3	Feecon	6.8
A-2950	9.5	A-2900	8.5	Feecon	8.2	A-2900	7.4	Elkhart	6.9
A-2900	9.5	A-2950	9.3	A-2950	8.5	Feecon	7.7	A-2900	7.0

At 75 psi, three units performed well (National, Elkhart and Feecon) producing 7.0 to 7.1% concentrations in spite of the very low inlet pressure, while the two Akron units exhibited their poorest performance yielding 9.5%.

The performance at 100 psi was less widespread with only a difference of 7.5 to 9.3%, but all units were well above the desired 6% concentration.

In the 125 and 150 psi ranges, the performance of all units began to come closer together with variations of 0.9% at 125 psi and 0.6% at 150 psi with all units in the 7 to 8% range at 150 psi.

At 200 psi, the performance was best for all units as they range from 6.3% to 7.0%.

Although all units were well above the 6% concentration level, it should be remembered that the concentration will decrease as hose length is increased up to 150 feet. This reduction is most pronounced at low flow rates (60 - 80 gpm) being as much as 1/3, but at higher flow rates (80 - 95 gpm) which is nearer the design range of the inductor, the change in concentration is minimal.

Flow Rate

The flow rates obtained from each inductor at various inlet pressures are shown in Table 3.

TABLE 3

FLOW RATE AT VARIOUS INLET PRESSURE

75 PSI	GPM	100 PSI	GPM	125 PSI	GPM	150 PSI	GPM	200 PSI	GPM
Elkhart	63	Elkhart	72	Elkhart	80	Elkhart	86	Elkhart	98
National	62	National	71	National	79	National	85	National	96
Feecon	60	Feecon	69	Feecon	75	Feecon	82	Feecon	93
A-2950	60	A-2950	67	A-2950	74	A-2950	78	A-2950	89
A-2900	60	A-2900	66	A-2900	73	A-2900	78	A-2900	88

As can be seen in Table 3, the flow rates varied from 60 GPM at 75 PSI inlet pressure to approximately 95 GPM at 200 PSI. The two units with the longer outlets (Elkhart and National) yielded the highest flow rates at 200 PSI inlet pressure, 98 and 96 GPM respectively.

Nozzle Pressure

The inductors were compared on the basis of the pressure drop produced at various inlet pressures and the results are summarized in Table 4.

TABLE 4

NOZZLE PRESSURES AT VARIOUS INLET PRESSURES
(50' Hose 95 GPM Nozzle)

75 PSIG	PSIG	Pressure Drop	100 PSIG	PSIG	Pressure Drop	125 PSIG	PSIG	Pressure Drop	150 PSIG	PSIG	Pressure Drop	200 PSIG	PSIG	Pressure Drop
Elkhart	43	32	Elkhart	57	43	Elkhart	71	54	Elkhart	89	61	A-2950	123	77
National	42	33	National	55	45	National	67	58	A-2950	86	64	A-2900	120	80
Feecon	39	36	Feecon	52	48	A-2950	67	58	Feecon	83	67	Elkhart	104	96
A-2950	38	37	A-2950	49	51	Feecon	62	63	National	77	73	Feecon	99	101
A-2900	38	37	A2900	46	54	A-2900	56	69	A-2900	70	80	National	99	101

Again, as can be seen in Table 4, the Elkhart and National units that have the longer outlets resulting in only a 7° taper, consistently produced the highest nozzle pressures since the pressure drops across these units were the lowest of the five units tested.

Height Test

The Akron A-2900 eductor was tested at heights of 2, 13, 23 and 33' and at inlet pressures of 90, 125, 150, 175 and 200 psi with 100' and 150' of 1-1/2" hose. The principal effect of height on an inductor prior to reaching its induction cut-off is to reduce concentration. There is not a significant reduction in flow or nozzle pressure because the inductive vacuum is being reduced and, at the same time, converted to outlet pressure. The results of these tests are shown in Table 5 and in Figures 4 and 5.

TABLE 5
EFFECT OF HEIGHT ON PERFORMANCE OF THE AKRON A-2900 INDUCTOR

100' Length of 1-1/2" Hose

	3'			13'			23'			33'		
Inlet PSI	Conc. %	Nozzle Pressure	Flow GPM	Conc. %	Nozzle Pressure	Flow GPM	Conc. %	Nozzle Pressure	Flow GPM	Conc. %	Nozzle Pressure	Flow GPM
90	9.1	42	62	8.0	40	61	6.8	38	59	5.3	35	57
125	9.3	56	73	8.3	58	73	7.8	55	72	6.7	54	70
150	7.8	67	79	8.6	67	80	7.7	66	79	7.5	66	79
175	7.1	77	84	7.3	76	84	7.8	75	84	6.5	76	85
200	6.9	85	90	7.1	85	89	6.7	85	89	6.7	85	89

150' Length of 1-1/2" Hose

	3'			13'			23'			33'		
Inlet PSI	Conc. %	Nozzle Pressure	Flow GPM	Conc. %	Nozzle Pressure	Flow GPM	Conc. %	Nozzle Pressure	Flow GPM	Conc. %	Nozzle Pressure	Flow GPM
90	7.5	39	60	6.5	36	58	5.2	36	57	3.5	35	56
125	9.4	56	72	6.9	54	70	6.4	52	70	5.3	50	68
150	7.8	67	79	7.5	66	78	6.9	65	78	5.9	63	76
175	7.7	77	85	7.8	77	85	7.1	75	85	6.8	75	84
200	6.7	85	89	7.4	86	90	6.7	85	89	6.6	85	89

With 150 ft. of hose and at a given inlet pressure, the flow decreased an average of 4 gpm across the full range of heights from 3 feet to 33 feet. However, the concentration fell from 7.5 to 3.5% as the inductor neared the cut-off point at 90 psi inlet pressure.

With 100 feet of hose, the performance was substantially better than with 150 feet with the concentration at 5.3% compared to 3.5% at 90 PSI inlet pressure. As expected, nozzle pressures were also a few pounds higher, generally three to four psi through the mid-range of inlet pressures.

With regard to height, all inductors will perform in the same manner as long as the "knee" curves are similar because this is the measure of when the unit will cease to induct. The point on the curve where the unit is producing 3.5% is well down the curve and close to cut-off, indicating that the inductor would most likely cease inducting AFFF with an additional 10 feet of height. The difference in outlet pressure between the 3.5% concentration and 5.3% is less than four psi.

CONCLUSIONS

1. Except for the qualification due to height noted in conclusion 2 below, commercially available inductors will produce a minimum of 6% AFFF concentration at inlet pressures from 75 psi to 200 psi.

2. The inductors tested will produce concentrations greater than 3.5% at nozzle heights up to 33' above the inductor with 150' of 1-1/2" hose with inlet pressures of 90 psi to 200 psi. In all cases above 125 psi, the inductors will produce concentrations of 6% AFFF or greater.

3. Inductors with longer outlet throats and tapers of 7° provided higher flow rates and higher nozzle pressures than inductors with short outlet throats and 10-12° outlet tapers at the same inlet pressures.

4. Pressure drop across inductors varies with inlet pressure; however, in all inductors the drop is from 35% to 45% across the 75 psi to 200 psi inlet pressure range.

5. Inductors with variable AFFF inlet orifices provide no significant advantages and, in fact, can be detrimental since the numbering dial can be easily misadjusted.

6. AFFF inlets are not uniform in diameter which could result in inability to match existing pick-up tubes.

RECOMMENDATIONS

The following are recommended as a result of this study.

1. The 95 gpm inductor be accepted as a suitable replacement for the portable FP-180.

2. The 95 gpm MIL-N-24408 nozzle be used with the inductor.

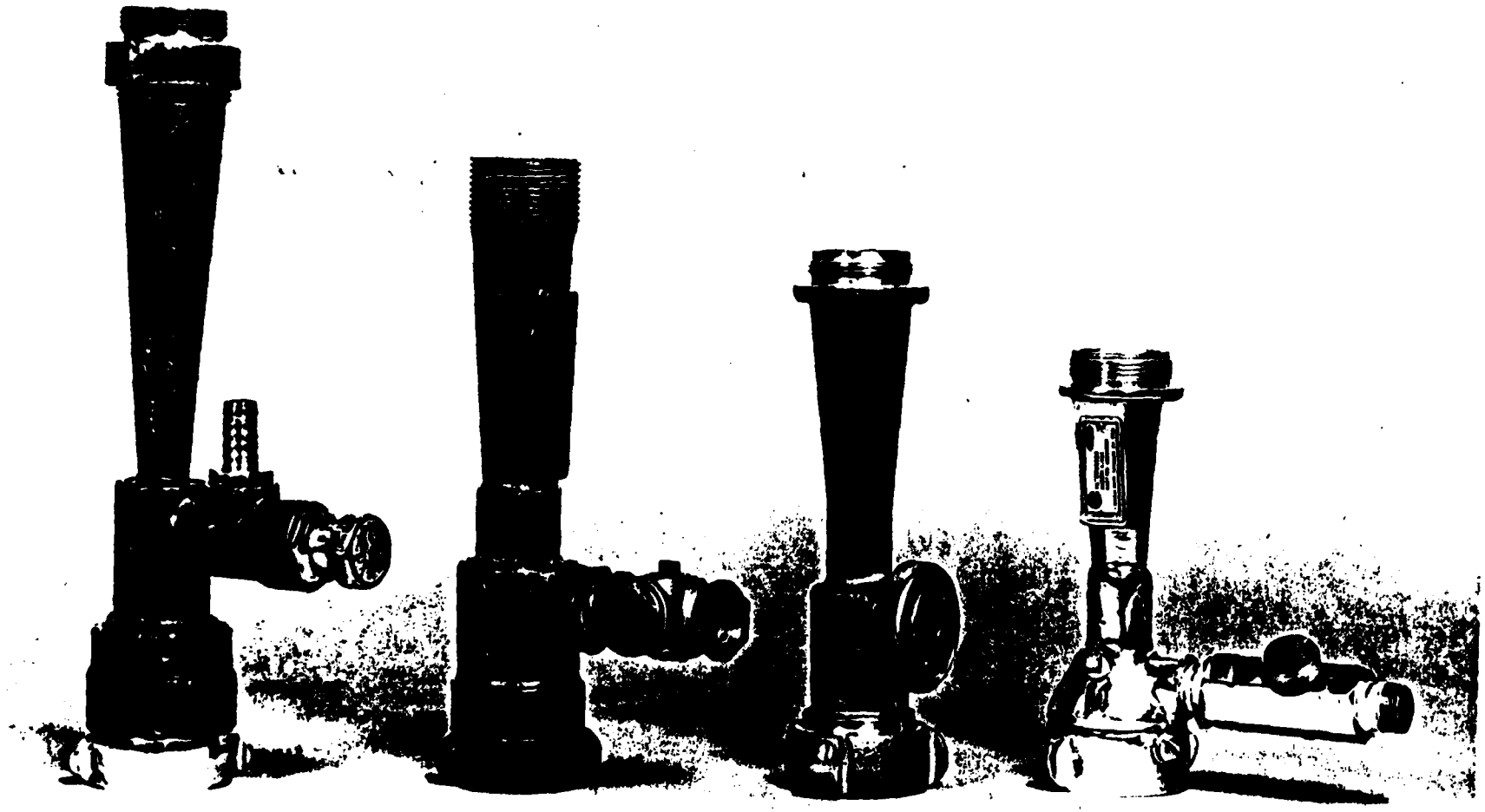
3. A MIL SPEC be developed for the 95 gpm inductors which incorporates the following requirements for construction.

   a. The pick-up tube connection (AFFF inlet) to be sized to match pick-up tubes now in the Fleet.

   b. All check valves be an integral part of the inductor and of a ball check type with a plastic ball.

   c. The AFFF inlets to have a fixed orifice and the following performance limits:

- less than 50% pressure drop between inlet and outlet pressures at all pressures from 75 psi to 200 psi;
- production of a minimum of 6% AFFF concentration in the 75 psi to 200 psi inlet range with 150' of 1-1/2" hose and a 95 gpm nozzle (MIL-N-24408);
- production of at least 3.5% AFFF concentration at 90 psi inlet pressure with 150' of 1-1/2" hose and a 95 gpm nozzle (MIL-N-24408) at a height of 33'.



Elkhart Brass Mfg. Co.

National Foam Systems Inc. Model LP-9A-165-200

Akron Brass 2900 2950

Feecon Corp. Model L-95-C

(Akron 2900 and 2950 are identical in exterior physical configuration.)

Fig. 1 — Commercial inductors tested

1. P_i Inlet Pressure - psi
2. P_t Throat Pressure - psi
3. P_o Outlet Pressure - psi
4. P_n Nozzle Pressure - psi
5. F_c Concentrate Flow
6. Ball Valve
7. Ball Valve
8. 50 Gallon Conc. Tank
9. Digital Weight Meter
10. $1\frac{1}{2}$" Hose
11. 90 GPM Akron Nozzle
12. F_w Water Flow
13. Ball Valve
14. Variable Height 3'- 40'

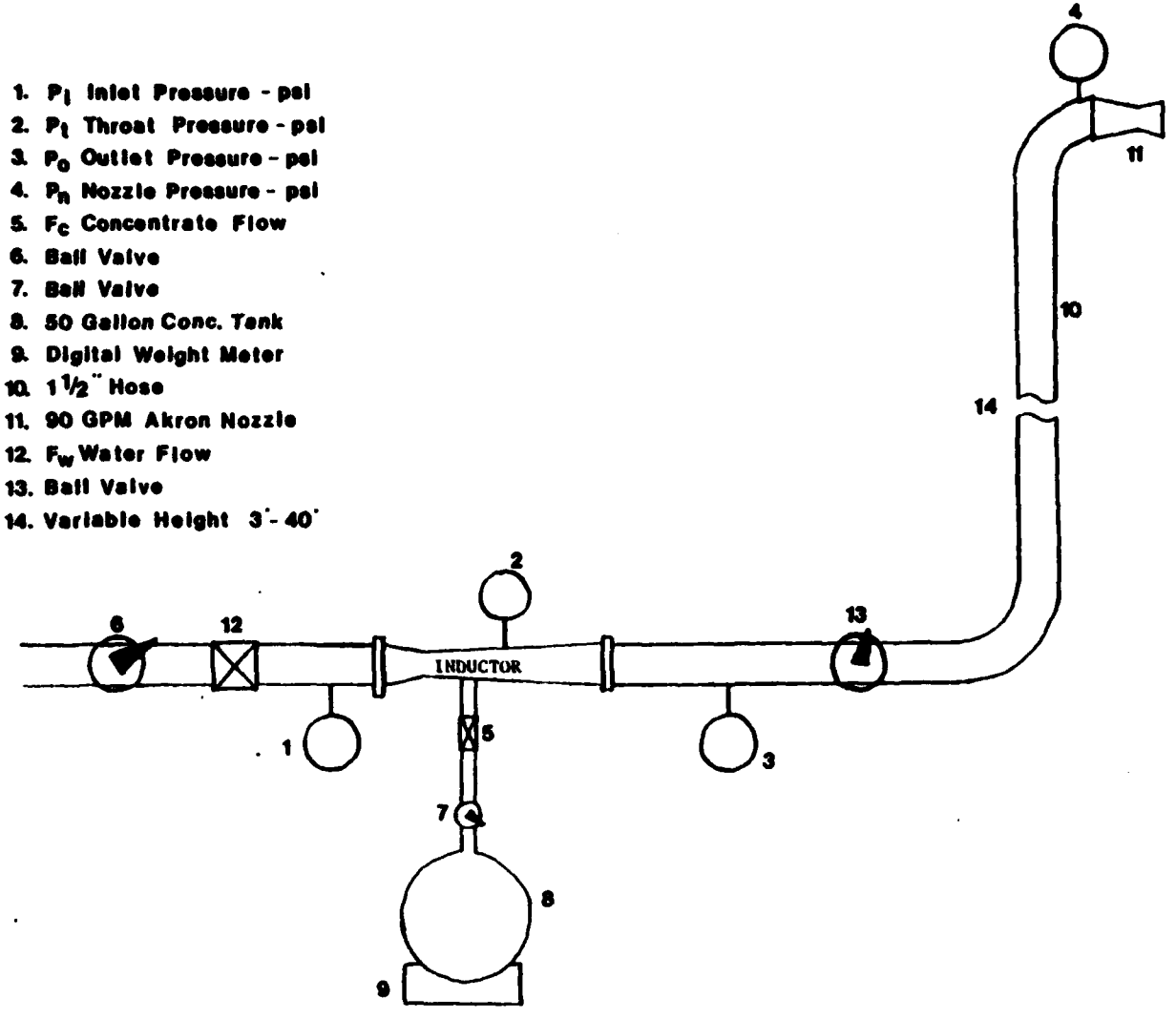


Fig. 2 — Test set-up for evaluating performance of inductors

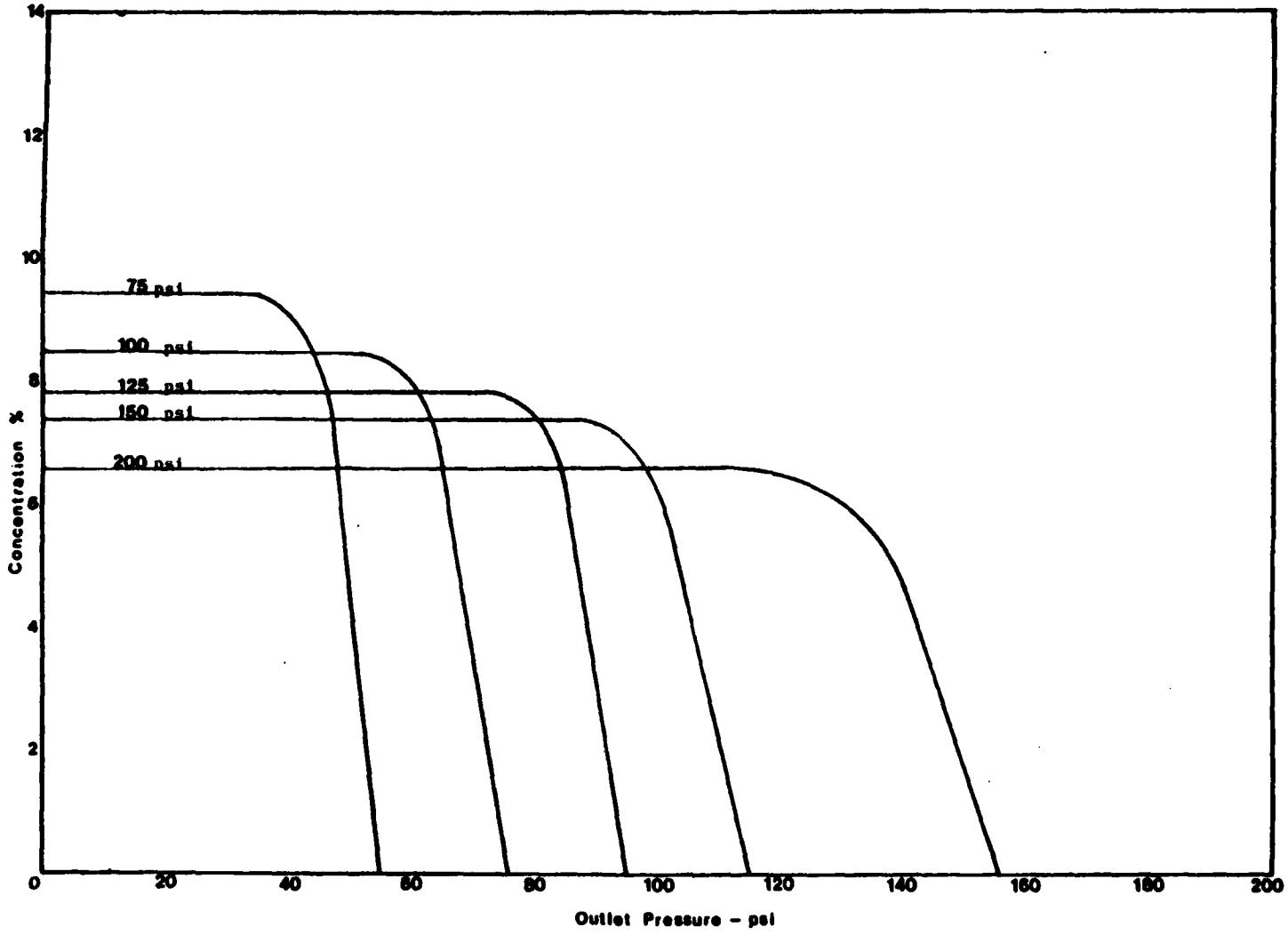


Fig. 3(a) — Performance curves for Akron Model 2900 inductor at various inlet pressures

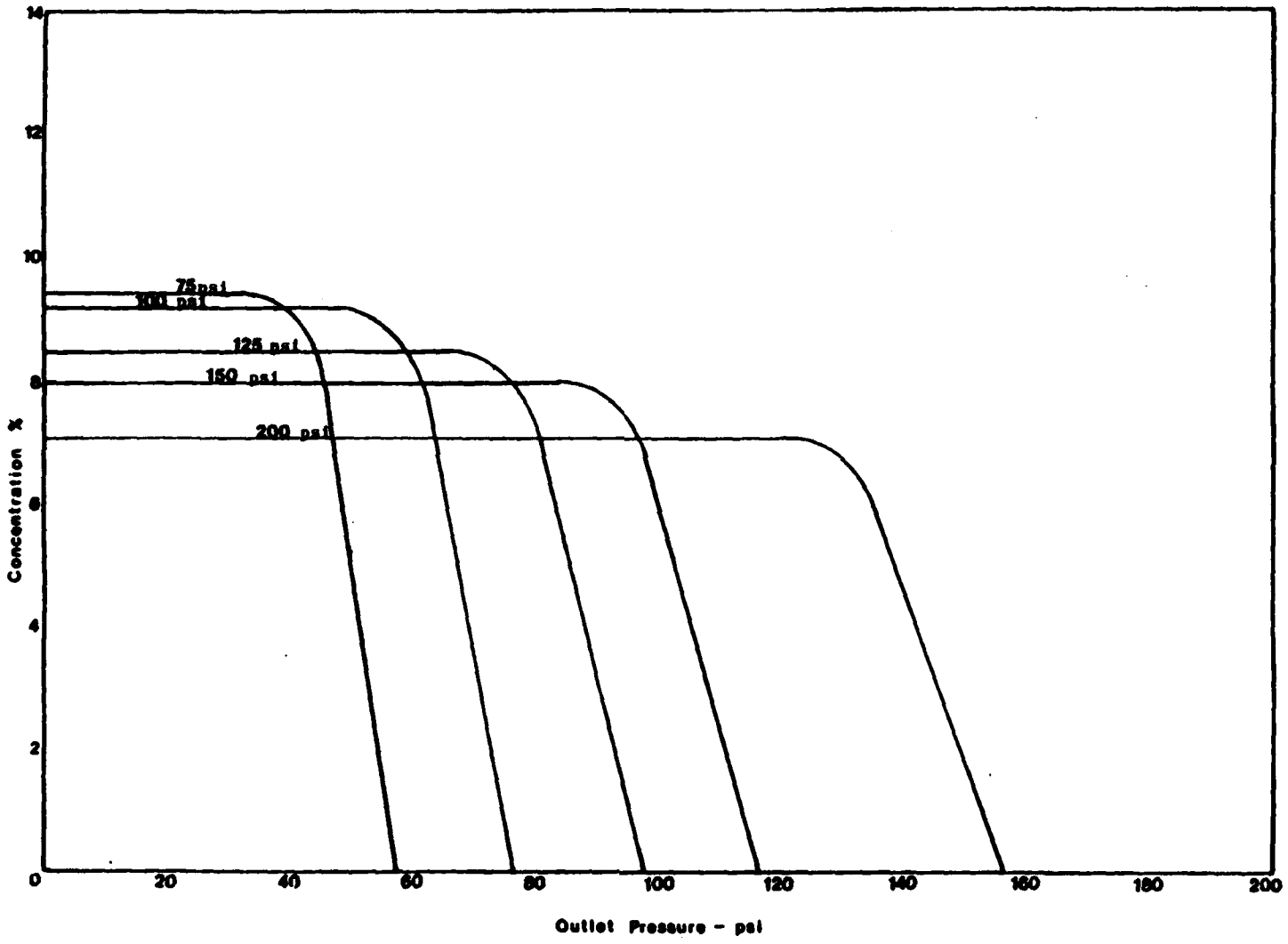


Fig. 3(b) — Performance curves for Akron Model 2950 inductor at various inlet pressures

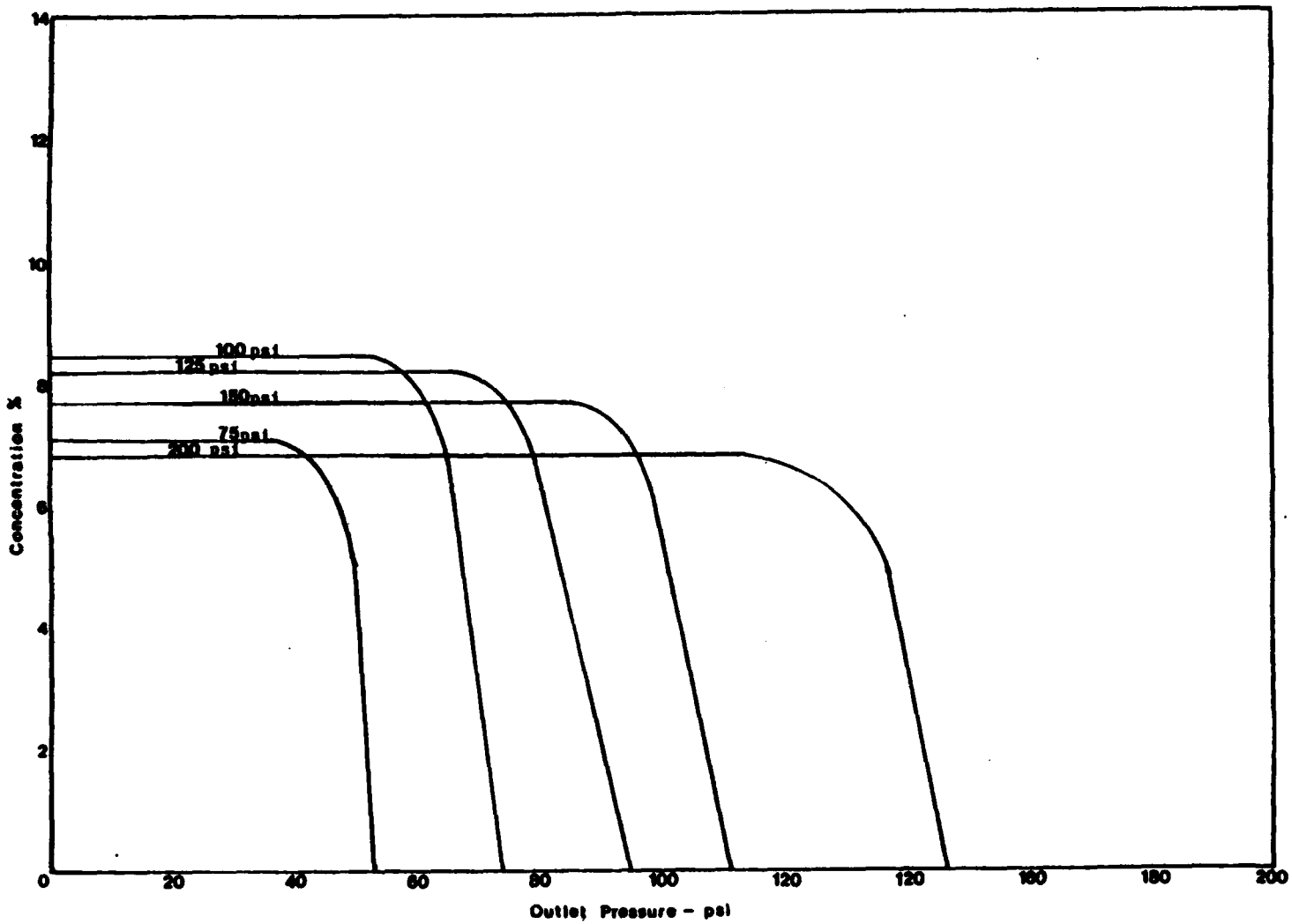


Fig. 3(c) — Performance curves for Feecon Model L-95C inductor at various inlet pressures

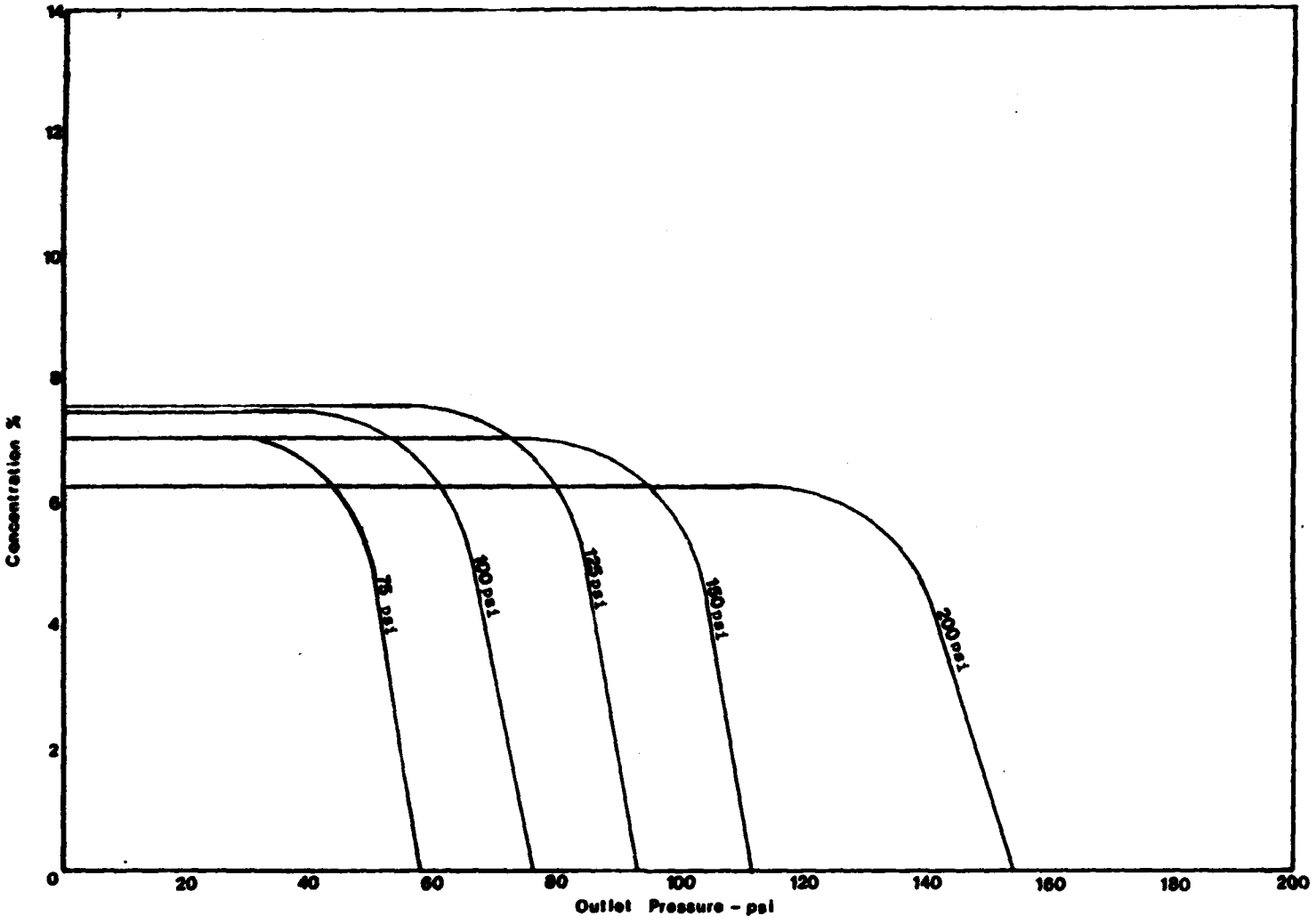


Fig. 3(d) — Performance curves for National Model LP-9A-165-200 inductor at various inlet pressures

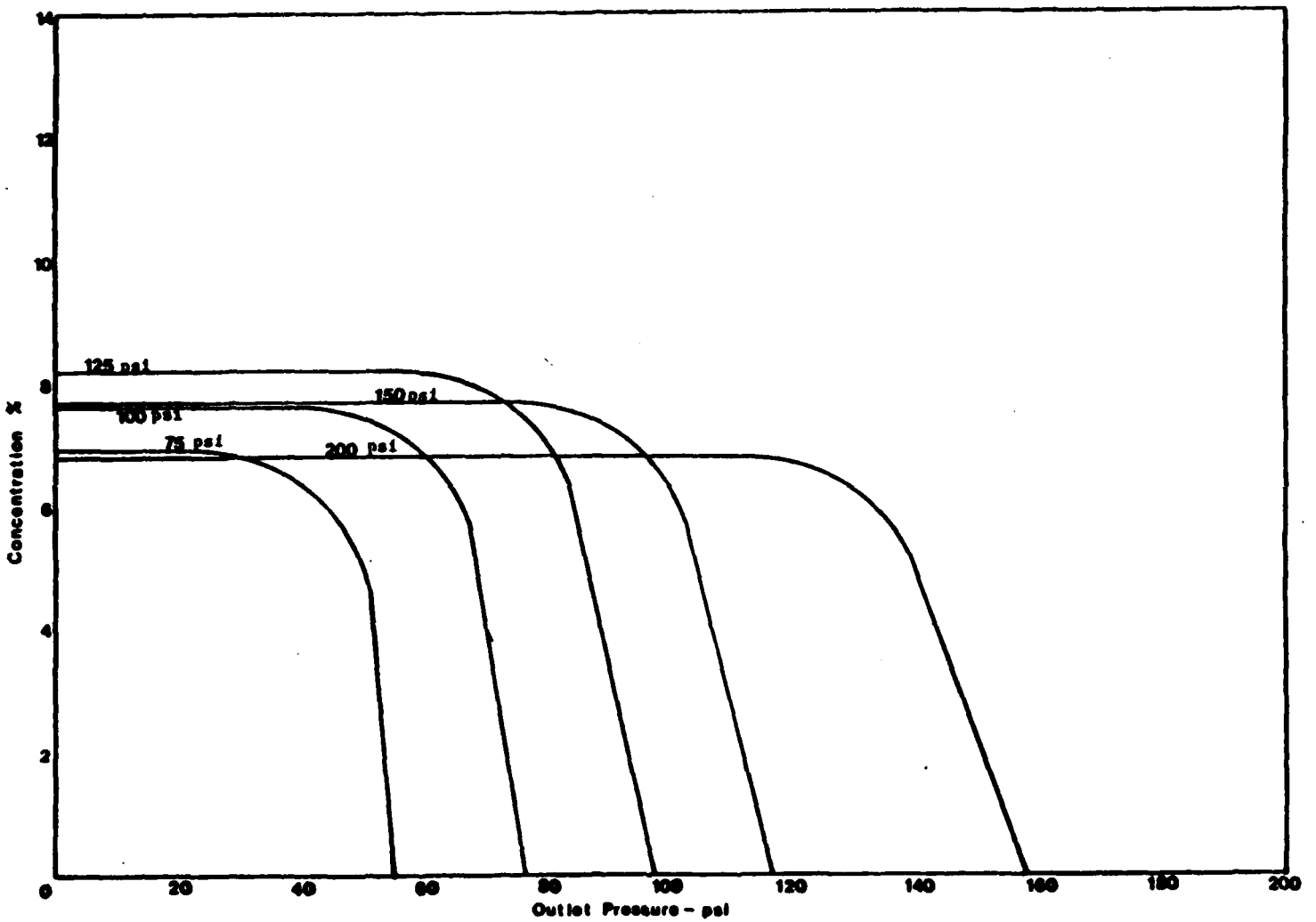


Fig. 3(e) — Performance curves for Elkhart Model 241-95 inductor at various inlet pressures

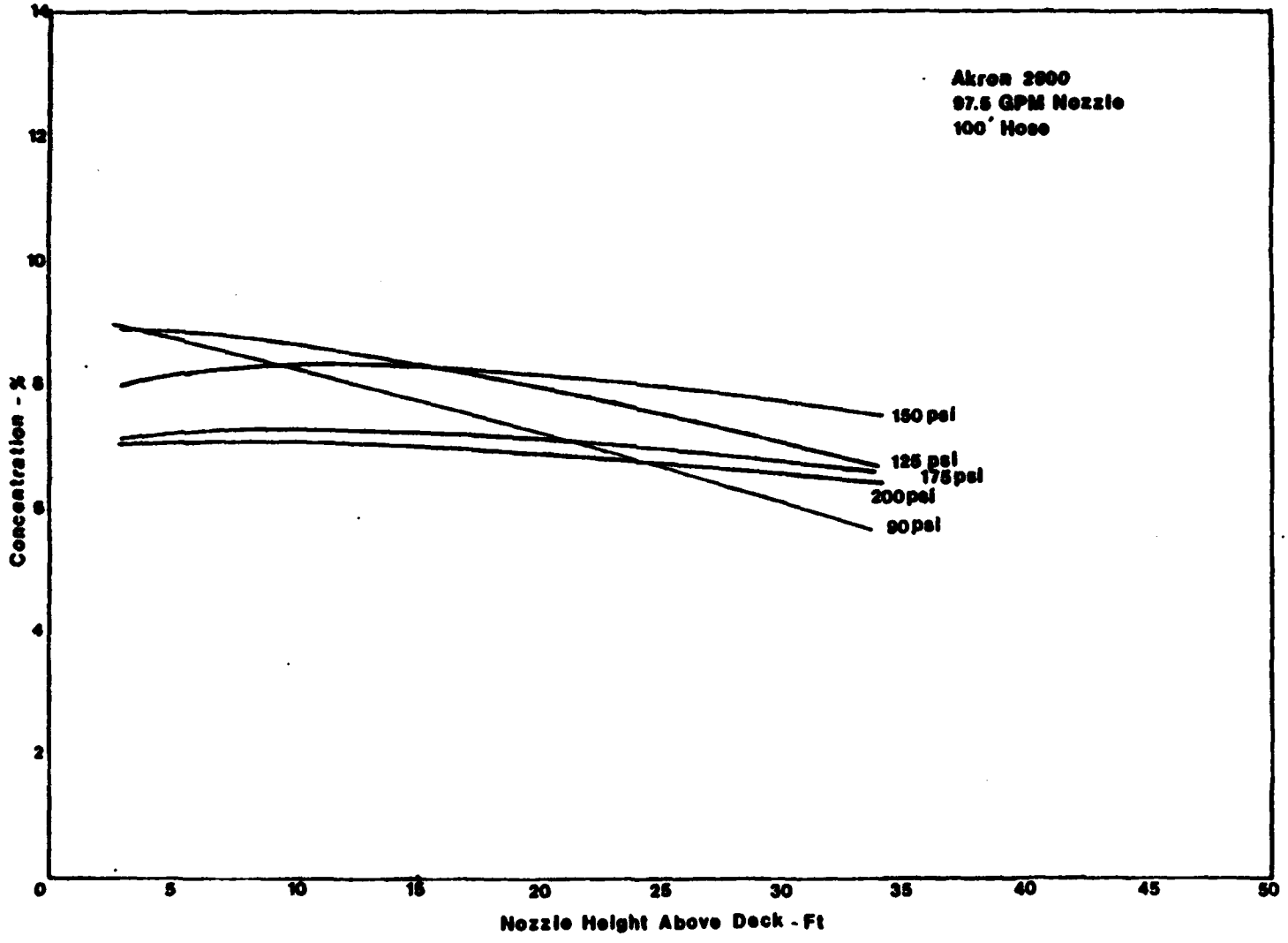


Fig. 4 — Effect of height on performance — 100', 1-1/2" hose

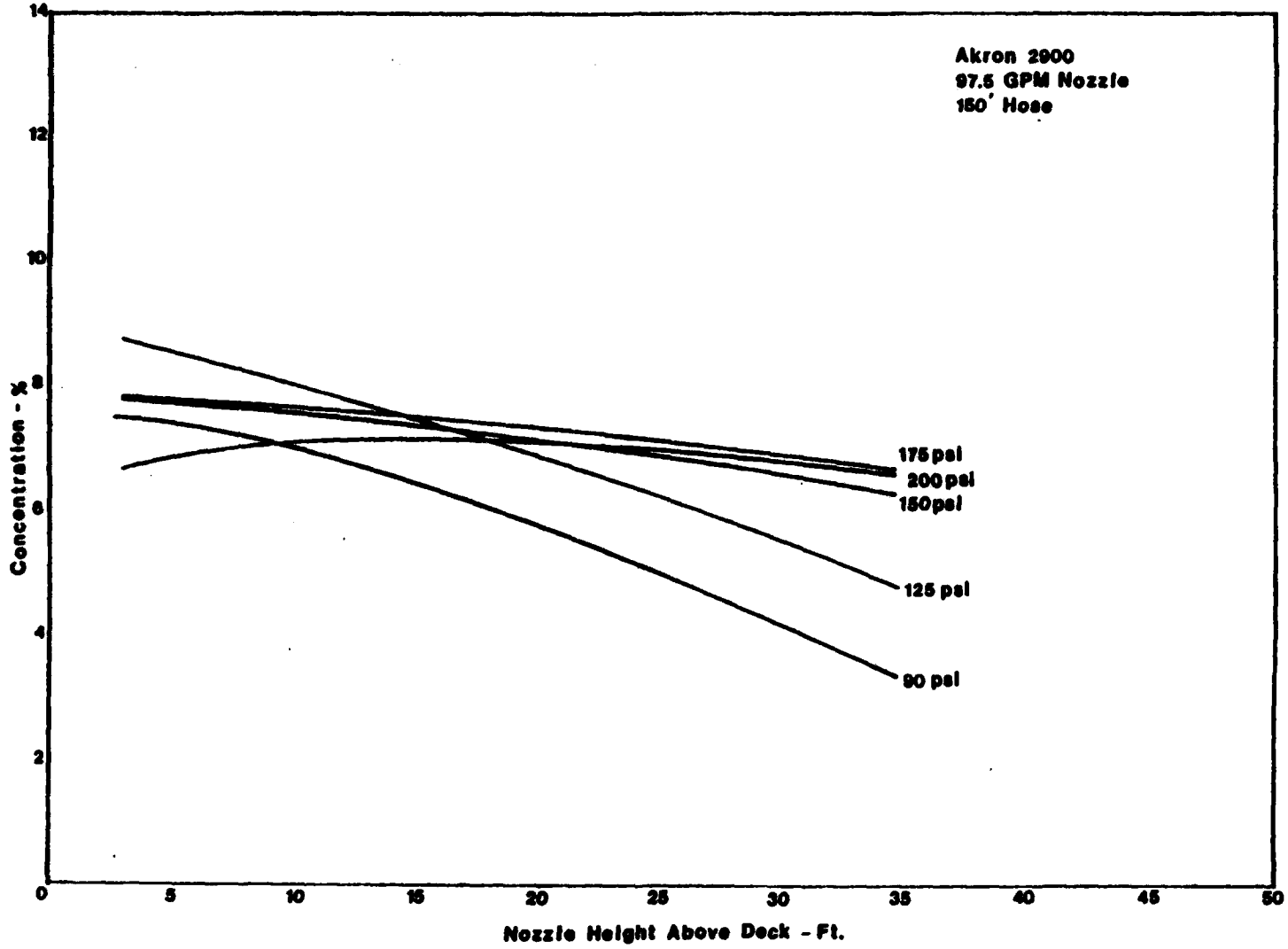


Fig. 5 — Effect of height on performance — 150', 1-1/2" hose